INSECT AND DISEASE CONTROL AS A BRANCH OF FOREST PROTECTION

By

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YALE UNIVERSITY · SCHOOL OF FORESTRY

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LECTURE

Delivered at Yale University, May 16, 1927
before the class in Forest Protection

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FOREWORD

PROTECTION of plant crops, whether such crops be agricultural or forest, assumes importance only as systematic growing of a given plant crop develops. The increasing interest throughout America in forest protection problems, particularly noticeable within the last few years, indicates that wood and timber crop production already is being practiced.

We are changing from the period of timber exploitation to one of timber production. Nothing emphasizes this better than the rising importance of forest protection. Unfortunately many foresters and landowners have as yet failed to envisage the full significance and importance of forest protection.

Because of these facts this publication is most timely. Although the lecture was originally delivered in the spring of 1927, unavoidable delays have prevented its earlier appearance in print.

INSECT AND DISEASE CONTROL AS A BRANCH OF FOREST PROTECTION

[*Paper read before the class in Forest Protection at the Yale School of Forestry on May* 16, 1927.]

CONTROL AS RELATED TO GENERAL CROP PRODUCTION

PRACTICALLY all of the timber grown in America up to the present time has been nature's free gift, produced without man's aid. This condition has caused American foresters to be "wild-woods minded" rather than "crop-minded." But there is evidence of a decided advance in forestry thought and practice. Forest exploitation is slowly giving way to conservative cutting. Better organization in forest fire suppression is developing recogniton of the necessity for forest fire prevention. Forest protection is more intensively applied as the crop viewpoint becomes established in forestry* (1, 2, 3).

The determined efforts of conservationists are reducing forest fire losses. There must be still greater efforts. But what has been accomplished in reducing forest fire risks makes it possible to give serious consideration to other phases of forestry which must be undertaken if future forest crops are to be adequately produced in the United States. For this reason, the time is here when protection of the forest from controllable pests (insects and fungi) needs to be recognized as being equally as important, even though not always so urgent, as protection from fire (4, 5).

Forest fire devastates more rapidly than forest pests and is a menace to animal and human life as well. Fire is always of emergency character, threatening complete forest destruction in restricted areas. Forest pests do not always create emergencies, but they are numerous and their robber activities go on continuously over vast areas. Quietly and insidiously insects and fungi are threatening man's control over the earth.

*Note: Numbers in parentheses indicate references listed on pages 27-28.

Referring to the war between man and the insects, William A. DuPuy (6) states:

> The issue is vital;—no less than the life or death of the human race. . . . There is no question but that the present greatest menace to man's dominance is the increasing strength of the insects. . . . To understand what is here going on, one must get a grandstand seat so that he can look down on this world game as on the plays of the baseball diamond. He must concentrate decades into single plays, centuries into innings. So may man and the insect be seen as they fight it out. . . . An understanding of these problems of the insect menace is largely due to findings of the present generation. Before it there were a few outstanding entomologists, but their numbers were small and their interest largely theoretical. The grasshopper invasion of the western wheat fields in the days of our fathers gave a tremendous impetus to applied entomology. Scientific men began to study the grasshopper, whence it came, how it might be fought. Individuals in the universities here and there began to specialize on a study of insects and their relation to human welfare. A generation ago so simple a thing as the fact that house flies bred in manure piles was unknown. A generation ago lumbermen did not know that a "red top" in the forest was a tree with its throat cut; that it was being girdled by a beetle beneath its bark which, if not fought, might destroy the whole forest. A generation ago there were few people who knew that the insects were man's most ambitious rival for world supremacy, and that the logic of the situation was that in the end they would probably wipe him out.

What applies to insects also applies to fungous and bacterial diseases. All crop producers soon learn that their greatest hazard is damage or destruction of their crops by pests. In this the producers of forest crops are no exception.

Whether fire or pest, forestry becomes impracticable without systematic protective measures. A forest fire may destroy all forest growth on a large area, but it does not exterminate a species throughout its range as chestnut blight is doing with our native chestnut. Fires destroy quickly but not continuously; pests destroy slowly but operate throughout the growing season, year after year. The cumulative losses from pests can exceed the losses from fire without the fact being realized, because insects and diseases work so extensively, steadily, and insidiously. The actual facts can be ascertained only after careful surveys of damage are made, and this is very

rarely done even on tracts under systematic forest management.

Those engaged in forest management are faced by pest control problems of the same general character as those which must be met by the growers of other kinds of crops. It is therefore desirable to take a bird's-eye view of the situation which confronts those who engage in the cultivation of plants as crops.

Plant Pests in Relation to Crop Production

The soil produces plants. Plants and their products are basic to the life of man and animals. The systematic production of farm, fruit, and forest crops is fundamental to civilization, industry, and commerce.

Profitable crop production depends mainly on three requirements. One is that the plants grown must be well suited to economic needs, and that cultural methods assure good yields under normal climatic conditions. The second requirement is that efficient means must exist for harvesting and marketing the crop. The third and very vital requirement is that, so far as practicable, the crop must be protected from damage caused by the elements, animals, parasitic and weed plants, fungi, and insects. Crop damage from storms, floods, frost, ice, snow, heat, drought, etc., is extensive and is largely unpreventable, but the huge crop losses due to fire, insect enemies, and fungous diseases of plants, weeds, and vermin, can be greatly reduced through care and effort on the part of the crop growers.

The loss from diseases and insects attacking agricultural, horticultural, and forest crops of the United States is conservatively estimated to be from three billion to four billion dollars each year (7), or from 20 to 25 per cent of the total annual crop production. These figures are necessarily only rough approximations. There is need for more accurate determination of crop losses from preventable causes. The valuable work done by the Plant Disease Survey and the Insect Pest Survey of the United States Department of Agriculture should be extended and supplemented. The time is rapidly approaching when increased population will force crop growers to greatly reduce the percentage of loss from preventable causes, since it

is not possible to greatly increase crop acreage, but it is possible to secure higher yields through thrift and care.

Protection to crops of the farm and orchard is given more readily than to forest crops, because intensive methods that are practicable under tillage are seldom feasible on rough and often inaccessible forest land. Furthermore, the annual cash return from an acre of cultivated crops is usually much greater than the annual cash return from an acre of forest crops. Application of intensive protective measures usually leaves a larger margin of profit on cultivated crops than would be obtained if such measures were not applied; whereas, in the forest, the normal margin of profit is so small that very definite limits are placed on the practicability of applying control measures.

Industry draws its supplies of raw materials from all parts of the world. As civilization becomes more complex, the distance and volume of crop movement increase, and transportation is more rapid. These conditions favor the introduction of insects and diseases from one region, country, or continent to another along with the plants and plant products moved. Each plant pest has its own restricted region of natural distribution and is further limited by the character of the food plants on which it can subsist. Modern transportation breaks down regional barriers, and thus new food plants become available. These new food plants are often better suited to introduced pests than the plants on which they lived in their homelands. There are still more than 5,000 species of dangerous insect pests and about 7,500 species of fungous enemies of plants which are known not to have reached America (8, 9). Plant pests may possibly migrate from one continent to another by the means nature has provided for their dissemination, but in the vast majority of cases such migration from continent to continent and from region to region is due, directly or indirectly, to human agencies.

In general, plant pests from foreign countries, which become established here when climatic conditions and food plants are favorable to them, are more dangerous to American plants than insects and plant diseases native to this continent. In a state of nature unmodified by man the parasitic enemies of plant pests hold the pests in check, or the plants attacked

become resistant to damage from their native pests through a long process of natural selection. When a plant pest is newly introduced into a region favorable to its development, its natural enemies are absent and its new food plants often are very susceptible to its attack. Thus the "balance of Nature" is upset, and before it can be restored long years must pass (10). In the meantime, valuable plant species find difficulty in maintaining their existence; in extreme cases species become extinct through the ravages of a pest.

Protective Measures Against Plant Pests

Three types of situations exist with respect to plant pests of economic importance to American crop production (11):

(a) The pest may be native or long established, in which case it is likely to have spread as far as conditions are suitable for its existence. Ordinarily the only practicable protection against pests in this class lies in sanitary cultural practices applied by individual growers; in other words, local control measures. Sometimes, however, these control measures may require extermination of "nuisance plants" in certain areas (e.g. common barberry in the Middle West; red cedar in the southern apple districts; currant and gooseberry bushes in white pine regions). In such cases quarantines against entrance of these nuisance plants into control areas are necessary.

(b) The pest may be of recent introduction and not widely established. Protective measures against this class may be aimed at completely exterminating the pest or at delaying its spread through quarantine and other general control activities until local control measures are worked out and applied (e.g. citrus canker in Florida; Mexican fruit fly and pink bollworm in Texas).

(c) The pest may not yet have gained entrance into the country. Protective measures against this class consist of quarantines which exclude, restrict, or regulate the entry of plants, plant products, or other products which are likely to harbor the pest.

The welfare of each individual, each industry, each state, and the entire United States is concerned in an adequate supply of plant material and plant products. A great volume of plant material and raw plant products is constantly required to be moved into the United States, into the various states, and within each state. Unrestricted movement of plants and plant products is accompanied by grave danger, because

destructive plant pests may thereby be distributed far and wide. Insects and fungous diseases thus disseminated have already caused severe crop losses in the United States. Diseases like chestnut blight and citrus canker, once established, may cause total destruction of a plant species and the industry dependent on such species.

One school of thought advocates no action to prevent distribution of plant pests, holding that limitation of movement of plant material and plant products is uneconomic, and that the proper means of combating plant pests is to scientifically breed disease-free strains of plants. The fallacy in this as a pest control policy is self-evident, because it is frequently impossible to breed plants to the necessary degree of resistance, and, where possible, it is a lengthy and costly process to establish such immune plants in place of the susceptible variety.

Another school holds to the belief exemplified by the erection of a monument to the cotton-boll weevil in honor of its services in stimulating better cotton production methods and diversification of crops in the South. The weevil reduces the yield and increases the price of cotton. Cotton growers reap a benefit from the increased price in proportion as they apply scientific methods in crop production.

This condition is favorable only so long as crop production equals or exceeds trade requirements. As population increases the demand, or as depletion of soil fertility decreases the possible yields, the effect of crop losses due to pests is to reduce national wealth and lower the scale of living for the mass of the population. Pests which are of wide distribution sometimes appear to have a beneficial price effect under a condition of agricultural overproduction. This, however, is only a temporary and artificial condition and in the long run produces serious economic results through underproduction in poor crop years. Pests which are not widely distributed place local communities at serious disadvantage in competing for markets. Crop production is most profitable when it is stabilized, and pests, if not controlled, tend to make crop production a gambling proposition.

Much of the economic loss from pests is due to the fluctuation they cause in crop production. Variation in the destruc-

tive action of a pest from year to year causes variations in yields and prices. This in turn stimulates overplanting or underplanting, since heavy increases in crop acreage usually follow years of high prices, and heavy reductions generally follow years of low prices. Thus pests prevent stabilization of production which the crop growers would otherwise approximate. (Variations in crop production attributed to climatic variations are frequently due to the favorable or unfavorable effects on pests of such climatic conditions.) Losses due purely to weather conditions can rarely be prevented by human action except in some cases through developing resistant varieties of plants. Losses due to pests are subject to great reduction through aggressive human effort. Until we have destructive pests under a reasonable degree of control, stabilization of production suitable to meet consumption requirements is prevented.

Native pests and foreign pests which are long established in a country generally cause less distress to crop producers and less disturbance to industry than new pests. One reason for this is that native or long-established pests are usually widely distributed, thus placing an equal handicap on the majority of crop growers. Another reason is that, as a rule, control methods for widely distributed pests have been worked out to the point of wide practical application. Still another reason is that widely distributed pests (and these are mainly native pests) commonly have many natural enemies to hold them in partial check. It is the new (and therefore mainly foreign) pests which cause the greatest economic ills under present conditions. Some foreign pests find conditions in America so favorable for their development that man is unable to combat them successfully. Given sufficient time and equipment, the scientist will seldom fail to find an effective means of dealing with a pest. But in recent years new pests have reached the United States in alarming numbers, and scientific research has not been increased to keep pace with the need. It is the height of folly to permit the introduction of any more foreign pests. Common sense and scientific knowledge support plant quarantine as a primary means of meeting the plant pest situation. This must be supplemented by de-

veloping local supplies of plant material produced under sanitary, pest-free conditions (12).

Scope of Quarantine Action

Plant quarantine consists either of complete prohibition of movement, movement regulated under inspection and sanitation requirements, or a combination of absolute and restrictive quarantines. In establishing any quarantine the economic benefit of protection against pests to a region, a state, or the United States should clearly outweigh the inconvenience, expense, and loss occasioned by interference with the free movement of plants and plant material. The only consideration must be the degree of danger from pests involved and the present and prospective economic importance of the crops which are menaced (11).

Restrictive quarantines should be laid when they will sufficiently accomplish the purpose sought. They are used (11):

1. Where adequate safeguards by inspection and treatment are known to be feasible.
2. Against diseases or insects of long establishment or wide distribution, where retardation of spread is believed to be the only object that is practicable of accomplishment.
3. Against diseases or insects of minor economic significance which can be at least partially controlled by inspection without heavy expenditure and without entailing heavy losses.

Absolute quarantines or embargoes should be employed only where restrictive quarantines are inadequate. An embargo is justified in cases (12):

1. Where the presence of the pest cannot be determined, by inspection, with a reasonable degree of certainty, and no method of treatment is practicable to insure freedom of the material from infection or infestation.
2. Where the nature or volume of the material involved makes efficient inspection or treatment economically impracticable.
3. Where there is risk of escape of injurious insects or establishment of a plant disease through plant shipments in transit or at the destination.
4. Where the elimination of host plants is under way in a region for the purpose of eradication or control of a pest, and these plants, whether healthy or not, may jeopardize the success of the eradication or control efforts.

The Need for Scientific Investigation and Cleaner Crop Production

Eradication of plant pests introduced into the United States has failed in most instances. Eradication measures, to be effective, must be prompt and drastic, and for this reason not only are costly but lack support from the public. Furthermore, to eradicate a pest its exact area of distribution must be known; otherwise it may be exterminated in one spot only to be found established elsewhere to such an extent that its eradication is an impractical proposition.

The only real, permanent protection against plant pests is based on exact scientific knowledge of all details concerning the life history, habits, habitat, food plants, and enemies of the pest. Eradication or quarantine measures cannot be expected to be fully effective against any pest unless it is known how to detect it in all its stages, on what plants it may be found, and where. Control measures also depend on this detailed knowledge, since methods of combating the pest are developed through taking advantage of some peculiarity in its life or habits or through introduction of its natural enemies (13).

Mankind has made great progress in preventing epidemics of pestilential diseases of human beings and domestic animals (14, 15, 16). It is reasonable to expect similar development of preventive measures against epidemics of plant diseases. We can depend upon science to lead the way to sanitary production of agricultural, horticultural, and forest crops, as public welfare demands it and as the public supports such work financially. The objective at which to aim is that advocated by Caldwell (17) with regard to human disease. He states:

> In his efforts to set bounds to a pestilential epidemic, man has always given proof of his impotence. . . . I mean that his success is impossible through the instrumentality of the restrictive measures usually pursued. I shall say, hereafter, that to no inconsiderable extent he may succeed. . . . When given in detail, those means will be found to be included chiefly, not in armed cordons or barbarous quarantines, but in CLEANLINESS.

The significance of Caldwell's statement can be appreciated only when it is noted that it was written in 1834, before there was exact knowledge of disease-producing organisms in medical science. Sanitation measures, until recent years, were the inefficient product of empirical methods. This student of medicine had the vision to foresee that prophylactic measures based on scientific principles would replace the crude disease-control practices of that day. Modern sanitation principles are finding wide application in farm practice, and eventually they will be adapted to forestry requirements.

Scientific research and experiment show what methods can be used to combat a pest, but the work requires a regulatory basis for practical application. Leadership is required to conduct a comprehensive, well-planned control program leading to general and effective application of control methods. The constant aim should be to develop control that is as nearly automatic as possible through the working out of natural processes. This may mean importing and establishing the parasitic enemies of pests or it may mean managing a forest area so that the ecological conditions are unfavorable to pest development but favorable to the forest crop (18, 19). This aim as applied to forestry is well stated—"Good silviculture, leading to forest hygiene (20)." Nature will control pests by one means or another, but unless aided and directed by human intelligence, the process is apt to be long and accompanied by great economic loss. When speeded up and directed by science, natural control tends to be both inexpensive and permanent.

Investigation and experimentation require time and money; hence, if a new pest spreads rapidly, control measures lag far behind the need for control. There is always a tendency to permit the need for speeding up control work to push aside the need for research and experimental work, thus slowing up actual accomplishment in control. Because time is the most important element in meeting emergencies due to the spread of new plant pests, plant quarantines are an essential part of pest control measures and indispensable to pest eradication. Quarantine cannot prevent natural spread of any pest within a region where the host plants are widely distributed, but it

can prevent rapid dissemination of infected or infested material through human agencies. This gives time for determining the biological and ecological facts regarding the pest, and for developing and systematically applying general or local control measures (21).

The time may come when human intelligence will be capable of applying such sanitary safeguards to the growing and transportation of plants and plant material that absolute quarantines will not be necessary. Service and educational work by agencies in charge of pest protection and control can do much to eliminate the need for restrictive measures, but so long as human nature remains fallable, it is essential to have a regulatory basis for such work to use where less drastic means fail to secure needed action. It certainly is true that much of our present trouble has its origin in lack of cleanliness in crop production. America must give greater attention to sanitation measures in the field and forest, since such measures tend to prevent insects and diseases from propagating and are extremely helpful in preventing them from being carried in crop shipments.

Clean crops lessen the danger, but we do not yet know of methods for completely disinfecting all shipments of plants and plant material. Hence plant quarantines frequently are imperative to the welfare of plant industry. A profitable crop-production area may be turned into a wilderness by a plant pest, so far as the plant attacked is concerned, or at least the area may be relegated to unprofitable production. For example, the establishment of the Mediterranean fruit fly in California would destroy the horticultural supremacy of this state and make it necessary to use the land for less profitable crops or for cattle production. We are painfully aware of the destructiveness of such introduced pests as the corn borer, cotton-boll weevil, chestnut blight, Japanese beetle, pink bollworm, white pine blister rust, gipsy moth, citrus canker, etc. To control their ravages and prevent introduction of similar foreign pests is a major conservation measure (22, 23, 24). There is wisdom in the old saying, "An ounce of prevention is worth a pound of cure."

THE FORESTER'S DUTIES IN PEST CONTROL

WHAT are the forester's responsibilities in pest control? What training should the forester have in this subject? The purpose of training in forest protection is to fix in mind those *principles* (or rules of action generally applicable) which will enable foresters to adequately meet forest protection problems in any part of the country and under any conditions which may arise (25).

I believe the matter of protecting the forests from new plant pests has not received, in the forest protection courses of American forest schools, the attention to which it is entitled. I feel that the teaching of this subject has been too often an effort to give details of the life histories of insects and fungous diseases, rather than to instill the broad principles governing their control. In the following discussion I shall outline my individual conception of these principles, but I do so realizing fully that at present our knowledge is inadequate for the task of formulating rules that will fit all conditions. All I hope for is that my statement of elementary principles will be reviewed and revised by those experienced in plant pest control work until the principles are clearly and accurately developed. In dealing with this subject I cannot speak officially for the United States Department of Agriculture; this paper represents merely my personal views.

Training in forest protection as it relates to insects and fungi should give the student a broad outline of the history of forest epidemics and of control practices so far as they have been developed here or abroad. The general principles governing pest control should be clearly stated. Stress should be laid upon the necessity of being constantly alert for evidence of damage from invading pests, and the student should be supplied with abundant material so that he may become familiar with the type of damage done by the various classes of forest insects and fungi. Following this, the life histories of type insects and fungi should be taught; this should come last in order that the student may realize that his chief concern as regards pests is to detect incipient damage and to plan and carry out control measures under the advice of specialists in forest entomology or forest pathology. Teaching of this

character, however, requires the student first to be well-trained in botany as applied to forestry, with a good knowledge of plant physiology and ecology.

Duties of the Individual Forester in Pest Control

Foresters have both individual and collective responsibility in combating plant pests. The individual forester is the guardian of the forest under his administration and has the duty of being prompt in detecting pest damage and in having an accurate determination made of the causal organism. Failure to report the presence of a new pest, because the forester who found it considers it an unimportant matter, may materially assist forest pests in becoming established in the United States. The individual forester also has the duty of applying control measures when it is possible and economically feasible.

Those responsible for the care and management of forest areas should have a pest detection force similar in purpose to the fire detection forces. This may consist of assigning a well-trained, capable observer to this job in connection with other duties which will give him ample opportunity to detect pest damage at the start. In large forest organizations a special man, or men, should be employed. The important point is to have management plans provide for pest detection and control.

As forestry develops in America and as fire prevention work becomes effectively organized, foresters will find it advantageous to maintain forces of men for general forest protection work. These men will have as their chief duty the maintenance of the forest in a sanitary condition as regards pests—both native and introduced, but they will also form an auxiliary forest fire force.

In the present undeveloped condition of forestry, probably the most effective means of securing such control application as is most necessary and practicable is through coöperation of a number of owners of adjoining tracts, with or without the leadership of state or federal agencies. Because forestry is in an elementary stage, the public does not readily undertake forestry measures. For this reason, and also because those who lead and teach forestry action have not yet progressed in knowledge to the point where they can give a forest owner

competent instruction without first-hand information on the exact nature of the conditions on the tract and on the owner's ability to perform the required work, service work by a governmental agency to give individual instruction to forest owners is essential if control work is to be done adequately.

Duties of the Forestry Profession in Pest Control

Collectively, foresters have the duty of leadership in protecting the country against the introduction of new pests, and in developing and applying control measures for pests of economic importance that are already here. It is the duty of the forestry profession to take a constructive position on pest control by fully recognizing its importance as a branch of forest protection and as a primary conservation measure. The profession has taken this constructive stand with regard to forest fire prevention and has developed general principles and policies for dealing with the local and national application of fire control measures.

I shall attempt to outline a set of principles for dealing with one phase of this matter, limiting application to that branch of forest protection with which I am most familiar; namely, protection from pests recently imported from other countries and not generally distributed. Native or widely established foreign pests constitute a different problem.

The protection of a forest against a pest recently introduced can be likened to the defense against an invading human army. The defending army is under direction of well-trained leaders. The first thing to find out is the strength of the invaders, where they are located, their probable line of attack, and their points of weakness. For this information the commander in chief must rely on his scouts and the intelligence department. Based on this information, the commander plans his campaign and moves his forces into battle line with the object of repelling or overpowering the enemy.

In warfare against forest insects or disease the forester should be commander in chief of the army of defense. The scientific investigators, ecologists, forest entomologists or forest pathologists as the case may be, must be relied on for the development of the ordnance and ammunition as well as the intelligence department. They furnish the forester with

information as to the identity, nature, and habits of the pest, direction of its probable advance, its points of weakness, and the methods through which it can be attacked.

The analogy between human warfare and warfare against imported plant pests falls down in one important particular which must be given special mention. In human warfare the object is to exterminate or drive out the enemy. In pest warfare, extermination is seldom possible and the effort commonly is directed toward suppressing the invader to the point of minimum damage; or, as Dr. E. P. Meinecke expresses it, "toward reducing the pest to the status of a tolerable nuisance." Common sense dictates that the economic law of diminishing returns applies in pest control application. The values preserved by the control work must exceed, or at least equal, the cost of such work if it is to be financially practicable. In some cases this will mean applying partially effective control measures; in other cases it may occasionally warrant an effort to completely exterminate the pest. Such decisions require reliable knowledge of the values which the pest will destroy if control is not undertaken and of the saving effected by different degrees of control at varying control costs. Such data must be obtained through control, valuation, and damage surveys, and through experimental work to determine the results obtained by variations in control practice.

Principles Governing Control of a Recently Introduced Plant Pest

The following principles apply mainly to control of a recently introduced plant pest by a large political unit, such as a state or the nation. They have a bearing because foresters of the future will necessarily have to take active leadership in work of this character. These principles are:

1. *Necessity for basic scientific research.* Scientific research is basic and primary to successful control of plant pests. Spend money generously for scientific research on the pest whose control is being considered or attempted, but insure that such research is closely coördinated with practical control efforts. Part of the research work should be determination of values threatened by the pest, where these values are located, and the economic limit of protection costs.

2. *Prevention of artificial spread.* The early establishment of a quarantine or quarantines is essential to prevent further spread of the pest by artificial means, but, to be most effective, quarantines established should be based on a rapid preliminary investigation of the mode of entry of the pest and careful summarization of the available facts of its nature, habits, and area of establishment.

3. *Determination of extent of spread by scientific methods.* Scouting, or systematic survey to determine extent of spread and degree of establishment of the pest, largely decides the scope and character of the plan of control. Extreme care must be taken in planning and organizing scouting or the control program will be based on mistaken hypotheses due to preventable errors. The following rules apply:

a. Assemble all available information and map out the scouting work with the thoroughness of a military campaign.

b. Assign men to scouting duties only after severe tests of their fitness and thorough training for their task.

c. Give scouts very definite assignments and require them to report daily on their findings. Prevent lowering of moral through failure to find the pest by requiring the scouts to report on location of specified host plants or specific field conditions. For this purpose, select things closely associated with the pest which can be found frequently enough to give the scout the satisfaction of accomplishment, but which are sufficiently difficult to keep him alert and ready to detect the pest if it is present. Checking is essential to both scouting and control work, but it must be done in a constructive and impartial manner. Check constantly and thoroughly on each detail, but make it clear to the workers that checking is scientific investigation for improvement of the work, and not criticism or detective work.

d. Beware of limited views as to the probable extent of distribution of the pest; scout a wide belt of territory outside of all known infected or infested areas; trace down all possible leads. In brief, blend extensive and intensive scouting so that when the work is completed it is certain to give a correct representation of conditions. It is not possible to examine every acre and every host plant in scouting. Therefore, the scouting system should be modeled somewhat on the strip survey system of forest valuation so that it will be possible to estimate the degree of pest establishment over the entire area surveyed, i.e. deduce how much additional infection or infestation is likely to exist from what is found.

e. Keep a "campaign map" showing results of scouting from day to day, and change scouting plans as conditions warrant.

4. *Basing of control policy and program on facts, and arrival at decisions in open conference.* A control program once under way cannot be changed readily in its scope, amount of funds appropriated, or general plan of procedure. Hence, the final summarization of scouting results must be a concise, clear, unbiased presentation of the facts, accompanied by first-class maps graphically presenting the fundamental data governing the control problem. A curve or chart showing the estimated momentum of spread and damage should be included.

The decision as to the advisability of undertaking control work should be made by an open conference of representatives of the industries affected, scientific and technical authorities in the subjects involved, conservation and trade organizations, and the general public. If control is decided as necessary and feasible, it is essential that the conference outline the main features of a clear-cut, tangible control policy and program covering a period of years. The conference should appoint a permanent committee to guide the later development of the program and stand ready to reconvene from time to time, as conditions warrant, so that the program develops its full strength and efficiency.

If this program is based on scientifically proved data, the further information which will be gained in the course of its application will not result in any fundamental changes, but only in secondary variations in the mode of application of these basic facts. An annual conclave of the control workers should be held at the end of each field season. The progress of the work should be reported and summarized, and detailed plans for advancement of the program discussed.

5. *Basing of control work on legal authority.* Leadership in any general pest control campaign is a function of government. Broad general policies, based on adequate regulatory legislation, need to be formulated. Careful thought is required to balance such policies and legislation so as to properly safeguard public welfare without improperly infringing on individual rights and without seriously handicapping control

efforts. If broad legal authority does not exist, the control program must provide for such authority. Legal means should not be used until persuasive measures through service and educational effort have been exhausted, but the law must be available and care must be taken to see that it is adequate to meet all necessary and reasonable control requirements.

6. *Service and educational work essential to extensive application of control.* In a control program of considerable extent, and particularly one involving general sanitation or destruction of host plants, the public must be fully apprised of the values threatened, the seriousness of the pest, and the necessity of coöperation. Pay close attention to public relations and education. Service work is needed to get landowners, or the persons responsible for production of the crop, to undertake and effectively carry out the control measures as soon as the experimental stage of control is passed. General educational measures and publicity are helpful, but man-to-man contact of a control specialist with the owner, on the tract where control work is needed, is the most effective means of getting control work done promptly and proficiently. The state or nation may bear part or all of the cost of control during the emergency period, but ultimately the burden must be assumed by the crop producer and the cost borne by the crop.

Control of Native Pests

Native pests and widely-established introduced pests offer a complex problem in the present undeveloped state of forestry in America. Damage from such pests sometimes assumes disastrous proportions over large areas but more often takes the form of a continuous, extensive, and subtle robbing of the forest crop. Specific campaigns against some of these forest enemies, under governmental leadership, can be productive of worth while results in some cases. In most cases, however, it is necessary for the individual forest owner to apply such local control measures on the tract under management as research and experiments have shown to be practicable and valuable. With pests in this class the forester must cope in about the same way that the farmer and horticulturist combat the general and well-known pests of their crops.

It is clear that the economic conditions governing forest management at the present time admit little being done in applying precautionary and sanitation measures against common forest pests in most sections of the United States. It is equally apparent that, as forestry itself becomes more practicable, it will be not only practicable but often essential to apply intensive measures for reducing damage from common forest pests. In preparation for such development, it is important that investigations be made by governmental agencies to determine the forest losses from preventable causes, including pests, and also to perfect control measures and demonstrate the practicability of their application.

As regards the immediate present, I believe that Angus Graham (20) has ably stated the case with respect to native forest pests. He says:

> The destruction of some 170 million cords of wood by the spruce bud worm between 1910 and 1918 raised an uproar which has reached every ear in Canada. Many have seen the damage for themselves, and the sight is shocking. At the same time, better-informed persons know that other pests, both insects and fungi, exist and cause a continual loss of wood in all our forests, quite apart from such spectacular disasters as that of the bud worm. Consequently a good deal has been said in recent years in favor of taking steps to combat these plagues; money has been spent, research has been undertaken, and the public in general has displayed a temperament favorable to vigorous measures.
>
> Now it is certain that the most vigorous measures are required from the public if our forests are to be saved from the pests, six-legged, two-legged, and legless, which beset them; but in order that the vigor may be properly applied the following facts should be given careful consideration.
>
> Research will tell us the life history of a bug or fungus and from this we can discover its vulnerable points and the weapons with which we can combat it. Thus the knowledge that the gypsy moth caterpillar had to walk up the stems of trees at one stage of its career suggested a method of combat; namely, to paint the stems with a band of grease that the caterpillar could not cross. (Such knowledge is of course essential if a direct attack is to be made.)
>
> But actually a direct attack on our bugs and fungi is out of the question. Traps, poisons, grease banding, and so on, are costly operations that can be and are employed with success in small scale, intensively managed forests; but the Canadian forest areas are so

huge, management is so conspicuous by its absence, and the sums involved would be so stupendous that a moment's consideration will show the impossibility of direct methods of combat.

But what has just been said is not a confession of failure or a wail of despair. On the contrary, there are a number of things which we could do to improve our situation without going in for scientifically perfect bug-killing. Every forester knows that pure crops of any species, particularly a conifer, are more liable to devastation by that species of special parasites than a mixed crop would be; yet we continually deplete our spruce and encourage a higher and higher production of balsam fir (which is the favorite food-plant of the so-called "spruce" bud worm). Every forester knows that trees which in youth have spent long years suppressed under the shadow of older neighbors are less vigorous and healthy in after life than those which have grown freely from the beginning; but nevertheless we allow "unmerchantable" hardwoods and undergrowth to stand over coniferous regeneration and suppress it for an indefinitely long period. And foresters apart, any housewife might suspect that it was unhygienic to leave the forests full of sickly trees, dead trunks, and rotten branchwood, all of which help in different ways to increase and spread both insects and fungi of different kinds. And yet we make no attempt to burn our slash.

Thus research, though indispensable for certain purposes, is unlikely to furnish us with any means of improving our present situation immediately; it is in fact inevitably above our heads, in view of the existing condition of the forests. At the same time it is clear that plenty of improvements can be made in our way of working the forests which will help toward the elimination of insect and fungal enemies, and which, though they may smack of common sense rather than of scientific precision, are yet absolutely necessary preliminaries to the more intensive methods of protection. And these improvements may be summed up by the slogan "good silviculture, leading to forest hygiene." In other words, the root of our trouble lies not in pests but in bad management. Let us, therefore, relieve our minds of any project of a definite anti-pest campaign, and direct our money and effort to making possible the introduction of proper methods of silvicultural management. Research is needed—as into the industrial uses of unmerchantable species. Field observation is needed—as concerning the habits of tree species and the cost entailed by improvements in logging practice. Above all, a vigorous and instructed public opinion is needed to secure a sane, just, and stable forest policy on the part of the Government, as without such a policy no improvement can ever be attempted, and study, research, and observation will simply be thrown away.

In conclusion, I desire to make it entirely clear that the purpose of this paper is to emphasize the hopefulness of the situation. Insects and diseases menace plant life, but man can combat them successfully if he acts intelligently and aggressively. For reducing damage from native or well-established foreign pests, sanitation measures are needed. For pests from abroad that have not yet been imported, exclusion measures are demanded. For foreign pests that have reached here, we must either undertake a campaign for their systematic control or philosophically accept the consequences of inaction.

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